MEETING THE CHALLENGES OF FUTURE AUTOMOTIVE HMI DESIGN: AN OVERVIEW OF THE *AIDE* INTEGRATED PROJECT

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SUMMARY

The general objective of the AIDE (Adaptive Integrated Driver-vehicle InterfacE) Integrated Project, funded within the EU 6:th Framework Programme (FP6), is to develop human-machine interaction (HMI) methodologies and technologies for the safe and efficient integration of driver assistance and information systems (including nomad devices) in future vehicles. The present paper identifies some major challenges for HMI designers of future in-vehicle systems, and describes how these challenges will be addressed by the AIDE project.

INTRODUCTION

The AIDE Integrated Project, funded by the EU within the 6:th Framework Programme, has been set up to address research on human-machine interaction (HMI) and development of HMI technologies within the eSafety framework [4]. The project started in March 2004 and will continue for four years. It gathers 28 partners, including the majority of the European vehicle manufacturers, a number of major suppliers, leading research institutes and universities. The AIDE IP is part of the "Integrated Safety Program", an initiative set up by EUCAR (the European Automotive Manufacturers' association for collaborative research),

consisting of a cluster of FP6 Integrated Projects and STREPs proposed, addressing the key aspects of Integrated Road Safety.

The paper is organised as follows: The next section identifies some major challenges imposed on automotive HMI designers implied by the eSafety development. Next, the scientific and technological approach adopted by the AIDE project for meeting those challenges is described. Finally, the project organisation and implementation, and links to other FP6 initiatives are outlined.

FUTURE CHALLENGES FOR IN-VEHICLE SYSTEM HMI DESIGN

In-vehicle systems can be roughly categorised into (1) Advanced Driver Assistance Systems (ADAS) and (2) In-vehicle Information Systems (IVIS). For present purposes, these are defined as follows:

1. *Advanced Driver Assistance Systems (ADAS):* Systems with the *main purpose* to enhance safety and/or comfort by *supporting the driver in performing the primary driving task.* Examples include lateral control support, collision warning, safe following, vision enhancement and driver fatigue monitoring.

2. *In-vehicle Information Systems (IVIS):* Systems with the main purpose of providing information to the driver *not directly related to the primary driving task*, including telematics and communication services, infotainment (radio, CD, DVD, mp3, email). These functions potentially impose a *secondary task* that may interfere with the primary driving task. An increasingly important sub-category of IVIS are so-called nomad systems, i.e. systems brought into the vehicle by the driver or passengers.

Thus, ADAS have the role of supporting the driving task while, by contrast, IVIS impose other tasks that may interfere with driving. These different functional roles of ADAS and IVIS lead to rather different HMI requirements, evaluation criteria and HMI design challenges. However, it should be pointed out that the distinction between ADAS and IVIS is not always this clear-cut. For example, a route-guidance- or vehicle diagnostics message, supporting the driving task on a high level, may still interfere with driving control.

Below, some key issues are identified for ADAS and IVIS respectively. Moreover, the challenges associated with the *integration* of multiple ADAS and IVIS, a key focus of the AIDE IP, is addressed.

Challenges for ADAS HMI design: Maximising the safety benefits of new functions

Advanced Driver Assistance Systems (ADAS) enhance the driver's perception of hazards, and/or partly automate the driving task. Examples include speed alert, lane support/blind spot detection, automated safe following, pedestrian detection, vision enhancement and driver fatigue monitoring. Since the role of ADAS is generally to support, rather than replace, the driver, the efficiency (and hence the safety impact) of these systems is strongly dependent on their interaction with the driver. Key issues and challenges include:

1. Efficiency of the perceptual enhancement: This concerns the extent to which a system's action (e.g. a warning) generates the appropriate response from the driver (e.g. an avoidance manoeuvre). New technologies, exploiting new concepts for driver-vehicle interaction in multiple sensory modalities (e.g. visual, tactile and auditory), offer great potential in this area. *The challenge is to find the best ways to exploit these new HMI techniques in order to maximise the efficiency of ADAS.*

2. Behavioural changes induced by ADAS: It is well known that the introduction of new safety functions may lead to unexpected changes in driver behaviour. This type of behavioural change, often referred to as *behavioural adaptation*, may significantly affect the actual benefits of a safety measure, both in positive and negative directions [8]. Examples of potential behavioural adaptation effects of ADAS include safety margin compensation and over-reliance on automation resulting in diversion of attention from the driving task and (see [12] for a review). *The challenge here is (1) to understand the behavioural mechanism underlying these phenomena and (2) to apply this knowledge to ADAS design in order to prevent the negative effects of behavioural adaptation.*

3. User acceptance and adoption: The safety impact of an ADAS ultimately depends on its market penetration rate and whether it is actually used by drivers. *The challenge is to develop methods for assessing these factors issues early in the design process.*

An example of existing work in this area is the ADVISORS EU FP5 project [7].

Challenges for IVIS HMI design: Minimising workload and distraction

By contrast to ADAS, IVIS provide services not directly relevant for the primary driving task and thus impose *secondary tasks* on the driver. The safety risks of distracting secondary tasks are well known, in particular the case of mobile phones. Results from an epidemiological study conducted by Redelmeier and Tibshirani [9], indicate that mobile phone use increases the accident risk by a factor 4 compared to normal driving. Given this potential safety impact of mobile phones alone, the introduction of additional information functions such as email, internet access, navigation aids androad/traffic information raises further concerns for road safety.

As mentioned above, a particularly important new class of IVIS is *nomad systems* (e.g. hand-held mobile phones, portable digital assistants and various combinations of these). The possibilities of seamless integration of these devices into vehicles via sort-range wireless links (e.g. Bluetooth) create an increasing convergence between personal and in-vehicle devices. Since the life cycle of an IVIS is substantially shorter than the vehicle's, it is expected that nomads will, to a great extent, replace traditional native in-vehicle systems in the near future. However, while nomad systems have great potential for increasing mobility, they are not designed for use while driving and are thus major potential distractors in future vehicles.

The general challenge here is to establish methodologies and technologies for minimising the negative impact of IVIS on the driving task. Of critical importance is to establish criteria for safe design together with methodologies for evaluating systems with respect to these criteria. Ongoing work in this area is being performed in the EU projects HASTE [3] and RoadSense [10]. Meeting this challenge also requires technological developments, e.g. exploiting new interaction modalities and/or techniques for real-time management of driver-vehicle interaction.

Challenges for integrating ADAS and IVIS

As outlined in the previous section, designing the HMI of individual future ADAS and IVIS imposes a number of tough challenges. However, as the number and complexity of n-vehicle systems increases, a further challenge of key importance concerns the integration of these systems into a functioning whole. Figure 1 below illustrates the situation facing automotive HMI designers in the near future.
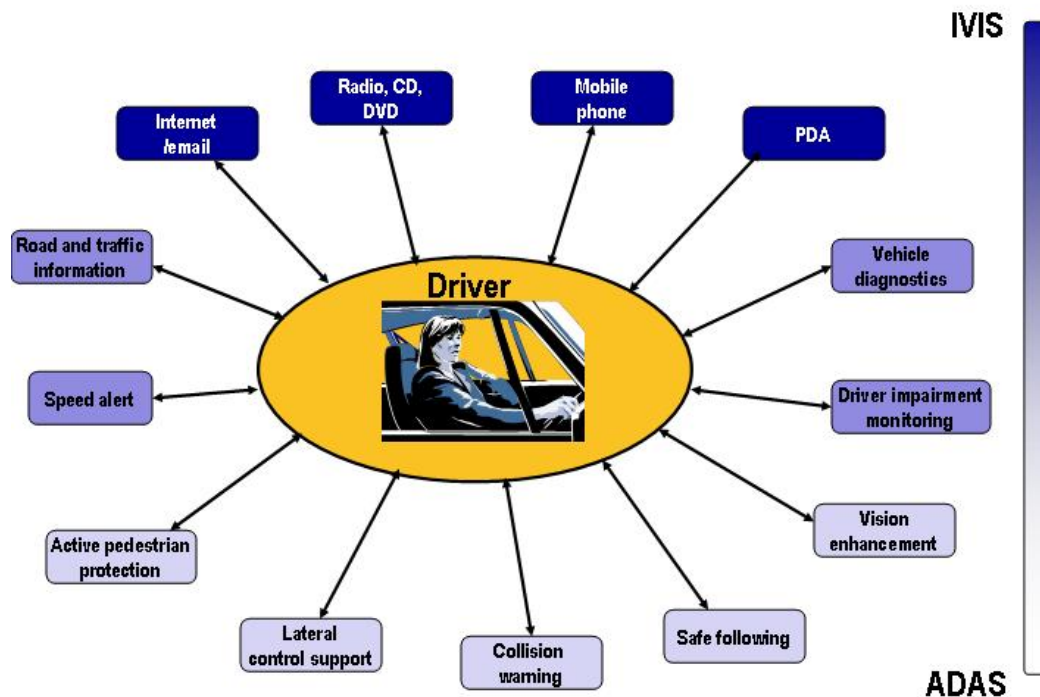

Figure 1. Examples of existing and future ADAS and IVIS interacting with the driver.

The proliferation of in-vehicle systems leads to a number of problematic issues:

- A large number of separate input/output devices would be difficult to fit into the cockpit
- Conflicting information from different systems may confuse the driver and induce information overload (causing problems that did not exist for the systems in isolation)
- Behavioural responses combined of systems may be very different from responses to the systems in isolation

On the other hand, this development also creates new possibilities, for example:

- Reducing cost by sharing of hardware components (e.g. displays and sensors)
- Exploitation of synergies, enhancing the performance of individual functions
- Enabling new, integrated, functions and services.

The challenge is to develop methods and technologies for a unified human machine that integrates different ADAS and IVIS (including nomad devices) into a functioning whole, resolving conflicts and exploiting synergies.

During the past decade, there has been a strong line of EU funded research and development on integrated adaptive HMIs, including GIDS [5], CEMVOCAS [2] and COMUNICAR [6]. In the US, similar work is currently being pursued in the government-funded SAVE-IT project [11].

THE AIDE APPROACH

AIDE objectives and scope

The general objective of the AIDE IP is to generate the knowledge and develop the methodologies and HMI technologies required for safe and efficient integration of current and future ADAS and IVIS into the driving environment.

In order to meet the challenges outlined above, the project integrates multi-disciplinary expertise and R&D facilities from Europe's leading research institutions and major industrial stakeholders. In particular, while the previous EU-funded work cited above has been of great importance for establishing the basic concepts for number of new automotive HMI technologies and methodologies, a key objective of the AIDE IP is to support further step of bringing the new HMI methodologies and technologies to the market. To this end, the project gathers the experience and know-how from leading partners in previous and ongoing European projects . Moreover, the strong industrial involvement creates potential for the establishment of standards.

Three main technical sub-goals have been defined:

1. Development of a model for prediction of behavioural effects of driver assistance and information systems. This model will be the basis for the design of the adaptive integrated driver-vehicle interface.

2. Development of a generic, industrially applicable, methodology for the evaluation of road vehicle human-machine interfaces with respect to safety. This methodology will be used for validating the AIDE technologies at the end of the project.

3. Design, development and evaluation of three prototype vehicles, one city car, one luxury car and one heavy truck, featuring adaptive integrated driver-vehicle interface technology.

Each of these sub-goals is addressed in a separate sub-project within the IP. The following sections describe the general AIDE concept and the sub-projects in further detail.

The AIDE concept

The general idea pursued in the AIDE IP is the concept of an Adaptive Integrated Driver-vehicle Interface, with the purpose of enabling the safe integration of multiple in-vehicle functions into a unified, natural, and intuitive interface towards the driver, managing the interaction between the driver and the various vehicle functions (the term "interface" is here used in a broad sense, referring not only to the hardware components - displays, buttons,

sounds etc. - but to all aspects the driver-vehicle-environment interaction). The general AIDE concept - a unified human-machine interface that resolves conflicts and exploits synergies between different ADAS and IVIS - is illustrated in Figure 2.
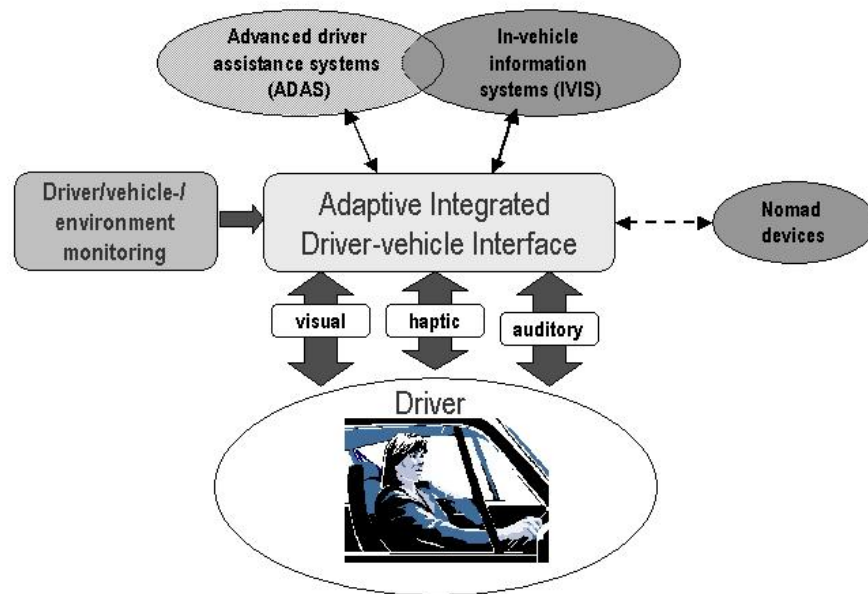

Figure 2. Illustration of the general Adaptive Integrated Driver-vehicle Interface (AIDE) concept.

The main features of the AIDE concept are:

1. *Multimodal HMI devices shared by different ADAS and IVIS* (e.g. head-up displays, speech input/output, seats vibrators, haptic input devices, directional sound output)
2. *Centralised intelligence for resolving conflicts between systems* (e.g. by means of information prioritisation and scheduling).
3. *Seamless integration of nomad devices into the on-board driver-vehicle interface.*
4. *Adaptivity of the integrated HMI to the current driver state/driving context.* The adaptive interface should also be re-configurable for the different drivers' characteristics, needs and preferences. This requires techniques for real-time monitoring of the state of the driver-vehicle-interface system.

The work in the AIDE IP is based on a set of basic tenets:

- **Systems perspective:** As stated in the eSafety Report [4], an integrated approach to road safety requires that the "*involvement of and the interaction between the driver, the vehicle and the road environment are addressed together*" (p. 11). This holistic, "systems"-, perspective will be adopted throughout the AIDE project, where the central object of study is the *driver-vehicle-environment system* (rather than any of these alone).
- **Multidisciplinary approach**: The realisation of the AIDE concept cannot be achieved by technological development or behavioural research performed in isolation. Rather, these must be addressed together by a strongly multidisciplinary team.
- **User-centred design and development:** Development of HMI technologies should not be driven by technology *per se*, but has to be based on user needs and expectations. This

requires a user-centred development procedure where design, prototyping and evaluation proceeds in an iterative, incremental way, involving end users and/or experts at each step.

- **Product focus:** The impact of new safety technologies ultimately depends on the deployment and market penetration of its results. Thus, AIDE will adopt a product-oriented focus, including near-product prototype development as well as identifying and addressing the main obstacles and enabling factors for market exploitation– e.g. acceptance by end users, requirements on the vehicle electronics architecture, organisational issues in product development and cost-benefit analyses of the AIDE technologies.

The AIDE sub-projects

The main RTD (Research and Technological Development) activities in AIDE, required for realising the general AIDE concept, are performed in three sub-projects (SPs). This section describes them on a general level. Sub project 3 is further described in [1]. Future publications will provide more detailed descriptions of the other AIDE SPs

SP1: Behavioural effects and driver-vehicle-environment modelling
In order to identify the basic requirements on an Adaptive Integrated Driver-vehicle Interface, a basic understanding of the interaction between the driver, the vehicle (including assistance and information functions) and the environment is needed. Research in AIDE will include empirical work (simulator/field studies) as well as modelling/simulation of the driver-vehicle-environment (DVE) interaction. The main initial goal of this research is to identify the key parameters governing the DVE interaction and safety-critical behavioural effects of ADAS and IVIS, e.g. behavioural adaptation and learning effects . On the basis of this analysis, two principal questions will be answered:

1. What adaptive integrated HMI functionality should be developed in order to best facilitate the DVE interaction and what are the basic design requirements for these?

2. What are the most critical behavioural parameters and scenarios to consider in the safety assessment of ADAS and IVIS, with respect to their HMIs?

The results from the SP1 analysis and modelling of behavioural effects will provide the starting points for the methodological and technological development in the project, pursued in SP2 and SP3 respectively. Sub-project 1 will thus be of key importance for providing a common conceptual framework, including taxonomies for IVIS and ADAS and their behavioural effects, to be used throughout the project.

The main expected result from SP1 is a thorough understanding of behavioural effects associated with in-vehicle technologies, embodied in models/simulations for predicting these effects.

SP2: Evaluation and assessment methods
In order to assess the safety benefits of different adaptive integrated HMI solutions, a scientifically validated evaluation methodology is needed. In order to have a real impact on road safety, the methodology must be easy to use and cost-efficient enough to be adopted by the automotive industry. Moreover, it should be sufficiently generic to be applied to a wide range of functions and standardised in order to enable the comparison of results from different test sites. The methods should also be linked to existing and future HMI design guidelines and

standards, in particular the "Statement of principles on safe and efficient in-vehicle information and communication systems", issued by the European Commission.

Work in SP2 will involve

- The development of methods and tools for quantifying the behavioural effects of integrated in-vehicle systems, with the focus on workload and distraction.

- The development of methods for extrapolating from these behavioural effects to actual road safety.

- The development of a general methodology for applying these tools at different stages of product development. This also includes development of standardised test scenarios.

The work in this SP also includes the human factors evaluation of the three prototype vehicles developed in SP3.

SP3: Design and development of an Adaptive Integrated Driver-vehicle Interface
The goal of SP3, which is the largest AIDE sub-project, is to perform the design and technological development of a comprehensive Adaptive Integrated Driver-vehicle Interface, to be implemented in three demonstrator vehicles.

The work in SP3 will involve:

1.Technological benchmarking and definition of use cases
This involves mapping the state-of-the-art in the field and defining the scenarios and use cases to be addressed by the AIDE system.

2. An open-systems architecture for AIDE
An open and flexible systems architecture is a key pre-requisite for efficient implementation of AIDE functionality. The goal of this sub-task is to define the AIDE system architecture and data-flow protocols on a semantical level (the underlying electronics architecture will be developed in the parallel EASIS project, to which AIDE has strong links). In order to facilitate industrial consensus on this important topic, an Architecture Forum will be established, which will provide an open forum for discussions on HMI architecture issues for all interested parties.

3.HMI design

a. Multimodal HMI input/output: This involves the design of new innovative concepts for driver input (e.g. speech input and haptic control devices) as well as system output (e.g. text-to-speech, head-up displays, haptic feedback through the seat, pedals or the steering wheel, 3D directional auditory warnings etc.) based on the exploitation of a wide range of driver-vehicle interface technologies.

b. Nomad system integration: Another key focus will be the investigation of concepts for safe and seamless integration of nomad devices into the driving environment. In order to facilitate interaction between key stakeholders, including the telematics industry, a Nomad Forum will be set up (with a similar role as the Architecture Forum mentioned above).

c. Centralised intelligence for management of information and adaptive functions
This involves the development of functions for integrating and resolving conflicts between the different systems. This includes prioritising between information initiated simultaneously from different systems, I/O device resource allocation, situation dependent information scheduling, real-time display configuration and situation-dependent selection of modality for presentation of information (e.g. visual, acoustic, tactile etc.). This also involves HMI personalisation and online adaptivity to driver characteristics, traffic environment, driver activity and state (as computed by the Driver-Vehicle-Environment Monitoring modules described next).

d. Driver-vehicle-environment monitoring
In order to enable the adaptive integrated HMI functions outlined above, techniques for real-time driver-vehicle-environment monitoring and driver identification are needed. The information required for computing the relevant parameters will be obtained from a set of onboard sensors (sensors on pedals, steering wheel, radar, eye-trackers etc.), or other information sources (e.g. GPS and digital map databases).

5. Prototype vehicle development
The AIDE system will be integrated and implemented in three prototype vehicles, a city car, a luxury car and a truck. As mentioned above, the human-factors evaluation of the prototype vehicles will be performed in sub-project 2.

SP4: Horizontal activities
This sub-project gathers a number of common activities, most notably the IP management, but also dissemination, exploitation and review and assessment of results. Another important horizontal activity is the development of HMI design guidelines and standards, based on the results from the three RTD sub-projects (1-3).

PROJECT ORGANISATION AND INTERACTIONS WITH OTHER INITIATIVES

Organisation and timing
The project is lead by a core-group chaired by the IP co-ordinator, Volvo Technology Corporation (VTEC). The other core group members are: BMW, Bosch, Centro Ricerche FIAT (CRF), Institute of Communication and Computer Systems (ICCS), EC Joint Research Centre (JRC), Peugeot Citroën Automobiles (PSA) and TNO Human Factors.

The technical leadership of the research and technological development sub projects 1-3 is performed by research institutes with leading expertise in the respective areas (JRC, TNO and ICCS respectively). In order to ensure the industrial relevance of the work, industrial vice-leaders have been appointed to assist the SP leaders (PSA, BMW and CRF respectively). SP 4 is lead by the IP co-ordinator (VTEC).

The AIDE partners are listed in Table 1.

Table 1. The AIDE partnership

Industry	Research Institutes and others
Volvo Technology (VTEC)	European Commission Joint Research Centre (JRC)
BMW Group Forschung und Technik	INRETS
DaimlerChrysler	TNO
Ford-Werke	Institute of Communications and Computer Systems (ICCS)
Adam Opel	German Federal Highway Institute (BASt)
Peugeot Citroën Automobiles	CIDAUT
Renault Recherche Innvation	Swedish National Road and Transport Research Institute (VTI)
Centro Richerche de Fiat (CRF)	VTT Technical Research Centre of Finland
Seat Centro Técnico	Centre for Research and Technology – Hellas
Robert Bosch	University of Stuttgart
Johnson Controls	University of Leeds
Siemens VDO	Linköping University
Motorola	University of Genova (DIBE)
KITE Solutions	ERTICO

Interactions with other FP6 initiatives

While the AIDE IP has been set up as an entirely self-contained and independent IP, strong links have been established with other initiatives in the 6:th Framework Programme. This section provides a brief overview of these interactions.

As mentioned above, AIDE will be part of the Integrated Safety Program (ISP), a cluster of FP6 projects in the Road Safety area, set up by EUCAR. ISP gathers projects on preventive and active safety applications (PPeVENT), vehicle electronics architecture (EASIS), safety-related telematics services (GST) and protective safety functions (APROSYS). The research in ISP will be harmonised through the ISP Steering Board, gathering high-level representatives from the industry. Moreover, a number of working-level interactions have been set up between the projects e.g. for ensuring compatibility between the technologies developed.

HUMANIST is an FP6 Network of Excellence focusing on HMI issues in the context of intelligent transportation systems, connecting the leading research institutions in the area (the majority of these are also AIDE partners). The research outputs from the NoE are targeted towards national and European authorities, standardisation bodies and European Integrated Projects. The AIDE IP is naturally an important such target. Thus, HUMANIST will provide the applied RTD work performed in AIDE with a strong foundation of basic research. Conversely, AIDE will provide HUMANIST with general feedback on the industrial research needs in the HMI area.

CONCLUSIONS

The first part of this paper outlined a number of challenges for designers of HMIs in future road vehicles. Different challenges were identified for Advanced Driver Assistance Systems (ADAS) and In-vehicle Information Systems (IVIS). The main purpose of ADAS is to support the driving task. Thus, the main challenge for HMI design of ADAS is to ensure that

the efficiency of the driver-system interaction is maximised. This requires an improved understanding of the behavioural effects of ADAS.

By contrast to ADAS, IVIS do not primarily support the driving task, but rather impose other (secondary) tasks. Thus, the main challenge for IVIS HMI design is to minimise the negative interference from these tasks (e.g. distraction and workload). This requires methods and tools for quantifying the effects of IVIS on the driving task and the relation between these effects and actual road safety. Importantly, these tools and methods need to be applicable by the automotive industry in production.

The third major challenge concerns the integration of multiple ADAS and IVIS into a functioning whole. This requires, for example, the development of technological solutions for sharing of multimodal HMI devices, prioritisation of information and HMI adaptivity to the driver, the vehicle and/or the driving environment.

The second part of the paper described how the AIDE integrated project has been set up to meet these challenges. The AIDE project gathers leading partners from previous EU-funded research in the HMI area. Based on this existing body of work, a general objective of the AIDE IP is to bring new HMI methodologies and technologies closer to the market. Only then they will have a real impact on road safety.

The main expected outputs from the project are:

- An improved understanding of behavioural effects of ADAS and IVIS, embodied in models and simulations of the driver-vehicle-environment system (SP1).
- An industrially applicable methodology for evaluating ADAS and IVIS HMIs with respect to safety (SP2).
- Three prototype vehicles demonstrating the AIDE concept (SP3) (validated by the methodology developed in SP2).
- General guidelines and proposal for standards for automotive HMI design (SP4).

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